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The judgement of absence in neglect

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Abstract—The usual way of looking at neglect is by investigating how neglect patients fail to detect that something *is* there. In this study, we look at how neglect patients correctly detect that something *is not* there. Patients with parietal lesions (11 with and 16 without neglect) and 23 control subjects indicated whether a dot target was or was not present in a geometrical display. While control subjects were consistently (and unexpectedly) faster in the no-dot than in the dot condition, the distinguishing response time pattern of right parietal patients with neglect was not—as one might expect—a relatively longer response time to left vs right targets, but a longer response time to target absence vs presence. This may be due to a serial search or, alternatively, it might result from double-checking for target absence, produced by lowered perceptual confidence. Since this "wariness" about stimulus absence seems to operate in parallel with neglect patients' denial of the deficit, we conclude that the response time pattern observed in this study could be used as a measure of subjective (un)awareness of neglect.

Introduction

Visual spatial neglect is usually associated with lower detection rates and longer response times (RTs) for targets presented on the side of space contralateral to the lesion. Research on neglect has consequently been concerned with understanding the defective processing of contralesional targets. But little attention has been paid to patients' performance in conditions when the target is actually *absent*.

Although patients with neglect generally behave as if the contralesional targets have ceased to exist, we know that even in severe cases the neglected stimuli may be processed to some degree [1–4]. Patients in these studies reveal a fair amount of perceptual and semantic knowledge about neglected targets, yet they also explicitly deny their presence or identity. Such dissociations between measures of implicit visual perception and explicit awareness of perception suggest that nondetection of left-sided information is different from nonresponse when a target is *not* actually present. As a direct demonstration of this, in an earlier paper [4], we reported a case study of a patient (FC) whose detection of verbally denied leftside targets was revealed by the fact that his latency distribution for *denied* contralesional targets matched the latency distribution for *detected* ipsilesional targets, rather than the slower distribution produced by true target absence. In observing our patient's behavior while performing this task, we were struck by the "difference between his assured manner when denying the targets on the left and doubtful tone when indicating true absence" (p.157). FC's doubtful tone would be consistent with his having some residual awareness of his deficit.

Can this simple detection task tell us anything about the phenomenology of denial, which is one of the most puzzling aspects of the neglect syndrome? Just as demonstrations of implicit perception cited earlier undermine the simple picture of pure unawareness of contralesional stimulation, so, too, would the discovery of specific deficits in dealing with target absence undermine the simple picture of unawareness of neglect (i.e., "denial"). For if the unawareness of deficit is absolute, then the performance of neglect patients with respect to target absence should match, at least qualitatively, the general performance of normal subjects.

In this study, we used the same detection task used with FC to study the performance of patients with less severe neglect. These patients acknowledged left-sided targets most of the time, yet all of them manifested neglect on standard clinical tests of copying and line cancellation or clock drawing, and denied any visual deficits. We

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compared the performance of this group with that of normal subjects, and of left and right parietal groups without neglect. We find that neglect patients do not show a lateralized deficit but instead, like patient FC, have substantially longer response times when the target is absent. However, this pattern was not present in the two parietal groups without neglect. Moreover, control subjects had their *fastest* response times when the target was absent. In our task, therefore, the response time deficit that discriminates neglect patients from normal subjects, and from the two patient control groups, is not lateralized—rather, it is a general elevation of response times when no target is present.

Method

Subjects

Nineteen right parietal patients, 11 with neglect (N) and 8 without neglect (RP); 8 left parietal patients without neglect (LP); and 23 neurologically intact individuals (controls) served as subjects (see Table 1). All but one of the patients were right handed. The mean age of the patients was 63 years and the mean age of the controls was 66 years.

All patients were referred on evidence of parietal or MCA infarction (confirmed by CT and/or MRI scans). Visual field deficits were assessed by perimetry or, in a few cases, by confrontation testing. Awareness/denial of neglect was assessed by first asking the questions: "Is there anything wrong with your vision?" and "When you look straight ahead, do you notice any difference in your vision between the right and left side?" All neglect patients denied or minimized their problems (e.g., claiming "I need new glasses" or "I have been told that I have some visual problems but I can see well").

Of the nineteen right parietal patients, eleven were diagnosed as having neglect if they omitted lines on the neglected side of space on a cancellation test, displaced numbers toward the ipsilesional side on a clock drawing task, and/or if they omitted or displaced parts of objects in a house and flower copying task.

Scoring

The line cancellation task consisted of 40 randomly arranged lines.

Mild omission: from 2 to 4 left side lines were omitted.

Table 1. Patient characteristics

Patients	Age	Gender	Lesion localization	Time since onset	Sensory-motor deficits	Line cancellation omissions	Object copying omissions/ displacements	Clock face distortions
N−								
RJ	80	M	Right OP	27 days	hma, hpr, tremor	mild	mild	mild
SA	61	M	Right FTP	2 years	hpr	mild	none	mild
BA	74	F	Right P	16 days	hpr	mild	mild	mild
CF	82	M	Right P	6 days	hma, hpr	none	mild	moderate
CM	61	F	Right MCA?	23 days	hpr	mild	none	mild
MP	71	M	Right FTP	20 days	hma, hpr	mild	mild	mild
CA	73	M	Right OP	18 days	hma, hpr	moderate	moderate	moderate
N+								
SA	78	M	Right P	2 years	hpr	n.a.	moderate	moderate
WD	33	M	Right OP	68 days	hma, hpl, seizures	mild	moderate	mild
CF	68	M	Right FTP	46 days	hpr	mild	moderate	moderate
BA	38	F	Right OTP	17 days	hma, hpr	mild	mild	mild
RP								
BT	67	M	Right OP	6 days	hpr	none	none	none
DS	38	F	Right OP	57 days	hma, hpr	none	none	none
DC	50	F	Right FP	42 days	hma	none	none	none
GR	65	M	Right FP	1 year	hpl	none	none	none
MY	81	F	Right P	40 days		none	none	none
RS	42	M	Right MCA-ACA Left F	41 days	hpr	none	none	none
TA	53	M	Right OP	30 days	hma, hpl	none	none	none
MR	30	M	Right OP	3 years	hma	none	none	none
LP								
GJ	56	M	Left OP	1 year	hma	none	none	none
HF	58	F	Left P	1 year		none	none	none
PM	35	M	Left OP	10 years	hma, hpl	none	none	none
RJ	60	M	Left OP	2 years	hps, mild aphasia	none	none	none
WG	80	M	Left OP	23 days	hma	none	mild	mild
BB	81	M	Left OP	1 year	hma	none	none	none
BP	57	M	Left OP	3 days	hpr	none	none	none
TP	88	M	Left OP	16 days	hma, hpr,	none	none	none

Key: N−: neglect patients without errors; N+: neglect patients with errors; RP: right parietal patients without neglect; LP: left parietal patients without neglect; O: occipital; P: parietal; F: frontal; T: temporal; MCA: middle cerebral artery; ACA: anterior cerebral artery; hma: hemianopia; hpr: hemiparesis; hpl: hemiplegia; n.a.: not administered.

Moderate omission: from 4 to 8 left side lines were omitted.
Severe omission: more than 8 left side lines were omitted.

The clock drawing task involved imagining a clock face and filling in the numerals on a blank circle except for the 12 o'clock numeral. For a detailed description of the computation of clock distortion, see Mijović [5].

Mild distortion: displacement of the 9 o'clock–3 o'clock axis away from the horizontal.
Moderate distortion: all numbers concentrated in the first three clock quadrants.
Severe distortion: all numbers concentrated on the right side of the clock.

The object copying task consisted of copying a drawing of a house and/or a flower on a separate sheet of paper.

Mild omission/displacement: up to 10% of the drawing was omitted or displaced.
Moderate omission/displacement: between 10% and 20% of the drawing was omitted or displaced.
Severe omission/displacement: more than 20% of the drawing was omitted or displaced.

Stimuli, apparatus and procedure

The stimuli and apparatus used were exactly as described and depicted by Mijović-Prelec *et al.* [4] and will be briefly summarized here. Subjects completed 8 practice trials and 32 experimental trials of a task in which they viewed a background figure made up of four gray squares and one larger open square superimposed on a large pair of crosshairs (see Fig. 1). On half of the trials, a small black dot was also present; in such cases the dot appeared half of the time on the left side of the figure and half of the time on the right side of the figure (and furthermore half of the time in the top half of the figure and half of the time in the bottom half of the figure). When the dot was present, subjects were to say "yes" into a microphone; when it was absent, they were to say "no" (the figure and dot appeared simultaneously at the start of a trial and disappeared between trials). Subjects were told to respond as quickly and accurately as possible. Their responses were recorded by an experimenter, and their response times were recorded by the computer that administered the task. Each subject performed this task twice (Blocks 1 and 2), separated by a series of five other tasks, all of which used the same basic stimulus pattern but assessed spatial relations encoding abilities (according to the theory of Kosslyn and colleagues [6, 7]) rather than detection. Unlike the task described above, the intermediate tasks had the dot present on all trials and required the subjects to choose from pairs of spatial relations (left/right; on/off; up/down; in/out; near/far). Results from these intermediate tasks are not reported here.

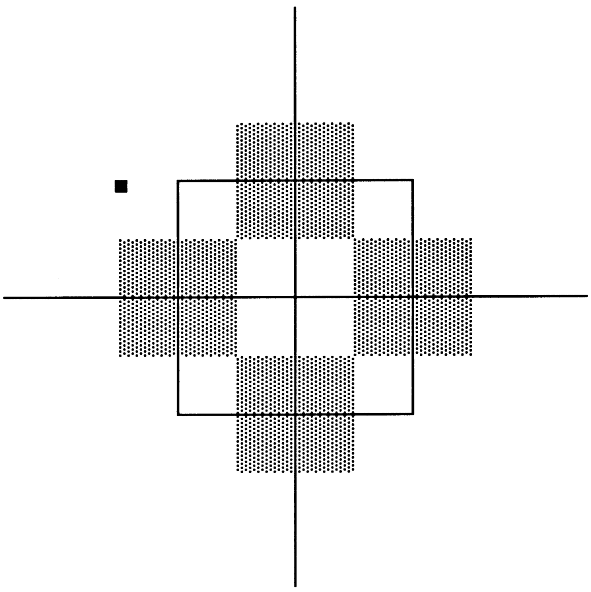

Fig. 1. Stimulus pattern with target on the left (a "yes" trial); in the "no" trials, the background pattern was present and the dot was absent.

Results

Table 2 shows the mean response times with standard errors for each subject group, block, and condition. Based on the results of patient FC reviewed earlier [4], we expected that neglect patients would show an inverted V-shaped pattern of response times. That is, they would respond more slowly on trials in which the target was absent ("no" trials) than on trials in which the target was present ("yes" trials) in either the left or right visual field. Thus, we performed quadratic contrasts on the mean response times for each group (the weights were -1, $+2$, -1 for the left/yes; no; and right/yes condition means) separately for the first and second blocks of testing. Since we operated with this strong prediction based on previous work, we report below one-tailed P-values for all t-tests of this contrast.

Figure 2 illustrates the results for the first block, which was completed by all but one of the 50 subjects in the study. The neglect group (N) shows the pronounced inverted V-shaped pattern found in patient FC. The right parietal patients without neglect (RP) and the left parietal patients (LP) show a lateralized pattern, both with elevated latency for left-side targets, and normal control subjects (C) show a shallow but clear V-shaped pattern. As expected, the quadratic contrast was significant for the neglect group, $t(10) = 2.312$, $P = 0.022$, $r = 0.590$, confirming that they took longer to respond to "no" trials than left-side or right-side "yes" trials. The same contrast did not approach significance for the right and left parietal groups, $t(7) = -0.802$, $P = 0.224$, $r = 0.290$ for the RP group and $t(6) = -1.3985$, $P = 0.106$, $r = 0.496$ for the LP group. Our normal control subjects showed the exact opposite pattern from the neglect patients, $t(22) = -2.002$, $P = 0.029$, $r = 0.392$, indicating that they were fastest in responding when the target was absent, an unexpected and intriguing result for a simple detection task.

The results for the second block, completed by 45 subjects, were very similar. Again, the inverted V-shaped pattern appeared and the quadratic contrast was significant for the N group, $t(8) = 2.796$, $P = 0.012$, $r = 0.703$. For the RP group a generally flat pattern replaced the lateralized one in the first block, but the contrast was again nonsignificant, $t(7) = 0.681$, $P = 0.259$, $r = 0.249$. The V-shaped pattern was again significant for the control group $t(21) = -4.527$, $P < 0.001$, $r = 0.703$. Finally, for the LP group the trend was the same as with the control subjects, and the quadratic contrast was likewise very strong, $t(5) = -4.4832$, $P = 0.003$, $r = 0.895$.

It is possible that the left hemisphere patients' elevated latency for ipsilesional targets in the first block is due to their high rate of hemianopia, which made them "over-attend" to their hemianopic field [8]. This compensatory strategy was probably rejected in the course of the five intermediate tasks and replaced in the second block by a more adequate one, resembling the performance of control subjects. The flat pattern of the RP group in the second block suggests that this group also benefited from the intermediate forced choice tasks.

For the entire neglect group, the mean error rate was 9% in the first block and 13% in the second block. However, virtually all of the errors were committed by just four of the subjects. If these subjects are excluded from the sample, the remaining essentially errorless subgroup shows the same inverted V-shaped pattern that we have just described, as shown in Table 3. For block 1 the quadratic contrast remains significant for this errorless (N−) group, $t(6) = 2.709$, $P = 0.018$, $r = 0.742$; for block 2 it approaches significance, $t(4) = 1.955$, $P = 0.061$, $r = 0.699$. The error prone (N+) subjects had a more ambiguous response time pattern. Given the small size of this group, we did not perform any significance tests, but we note that their RTs were consistent with the inverted V-shape on the second round of testing but not on the first, where instead they exhibited the longest RTs to left-side targets. Interestingly, in the second round of testing their error rate is no longer lateralized. Specifically, the error rate reduces from 63% to 22% for left-side targets, at the same time increasing from 9% to 19% for right-side targets. This redistribution of errors could be accounted for by a cumulative "cueing" effect of the five intermediate tasks (e.g., see [9], about the impact of forced choice tasks on neglect search) which likewise

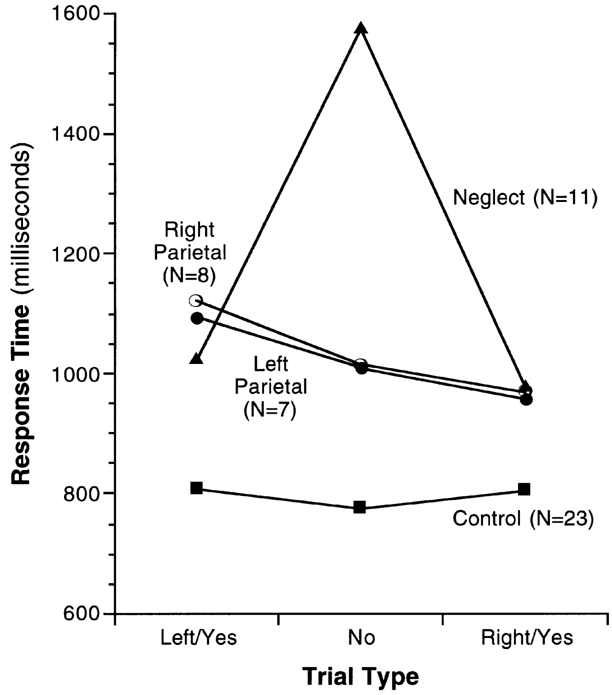

Fig. 2. Results from Block 1 of the experiment. Mean response times, in ms, for each subject group and trial type. Note the contrast between the pronounced inverted V-shaped pattern for the right parietal patients with neglect (N) and the patterns for the other subject groups (RP, LP, Controls).

Table 2. Response time results

	Block 1			Block 2		
Subject group	Left/ Yes	No	Right/ Yes	Left/ Yes	No	Right/ Yes
N: Right parietal patients with neglect ($N = 11$*)						
Mean	1022	1573	993	1141	1429	1080
Std error	50	270	69	184	260	180
RP: Right parietal patients without neglect ($N = 8$)						
Mean	1128	1014	986	1017	1065	1055
Std error	98	68	45	59	72	66
LP: Left parietal patients ($N = 8$†)						
Mean	1098	1011	973	892	859	906
Std error	42	42	51	40	46	78
C: Normal adult control subjects ($N = 23$§)						
Mean	808	774	805	800	731	766
Std error	28	27	25	26	23	24

Group means and standard errors, in ms, from the experiment, by subject group, block, and trial type.
* Two members of this group completed Block 1 but not Block 2.
† Two members of this group completed Block 1 but not Block 2; one member of this group completed Block 2 but not Block 1.
§ One member of this group completed Block 1 but not Block 2.

Table 3. Response time results

	Block 1			Block 2		
Subject group	Left/ Yes	No	Right/ Yes	Left/ Yes	No	Right/ Yes
N−: Neglect patients without errors ($N = 7$*)						
Mean	959	1879	1007	1283	1649	1238
Std error	56	377	98	329	458	317
N+: Neglect patients with errors ($N = 4$)						
Mean	1132	1154	1037	963	1155	882
Std error	74	173	102	49	78	43

Group means and standard errors, in ms, from the experiment for the two subgroups of neglect patients (with and without errors), by block and trial type.
* Two members of this group completed Block 1 but not Block 2.

could have produced defective performance for ipsilesional right-side targets.

As one may expect, the four error prone subjects demonstrated more severe neglect on the screening tasks and their lesion size were larger according to their CT and MRI scans. The two neglect groups, however, did not differ with respect to either hemianopia or post-onset recovery time. Whereas elevated error rate and longer latency for left-sided targets conforms to neglect patients' general pattern of performance, it is the error prone subjects' switch to a non-lateralized response pattern in the second block of trials that calls for attention. All four groups of subjects benefited to some extent from the forced choice set of tasks and it is probably by virtue of this intermediate experience that the error-prone subjects generated in the second block a response pattern similar to the one exhibited by the errorless neglect group. In other words, the intermediate tasks played, at least temporarily, a "rehabilitative" role by reorienting their attention to the left and by redistributing their limited attentional resources to both sides of space.

Discussion

The fact that neglect patients take more time to determine that a target is not present, may be given two distinct but not necessarily opposed interpretations. The first interpretation associates the finding with research on preattentive processing of targets embedded in an array of similar distractor elements [10]. In such tasks, normal subjects are quicker in detecting a target (which visually "pops out" from the array) than in detecting target absence. This is taken as evidence for parallel processing of features, and for serial search across the array when no target is present. Grabovecky and collaborators [11] have recently shown that preattentive visual search may be preserved in neglect patients. Similarly, in our experiment, the fact that neglect patients' response times to left and right targets are approximately the same, and shorter than response times to target absence, would be consistent with parallel target detection across different locations, and serial search—most likely from right to left—across the stimulus pattern in conditions when a target is not present.

This explanation, however, raises a further question: why do normal subjects not reveal the same pattern; i.e., why are they faster in detecting target absence? It is possible that control subjects are prepared to respond to the background "no" pattern, which is the single most frequent stimulus by far (appearing 50% of the time). This background pattern could serve as a perceptual template. In contrast, no template is available for either left or right target presence, because the dot can appear in many different positions.

It is also possible that the multiple symmetry and strong geometric shape of our background pattern further facilitates detection of target absence, in essence transforming the task into one of discrimination of symmetry (target absence) from non-symmetry (target presence). Normal subjects may be using a "symmetry detection strategy" (e.g., see Palmer's theory of symmetry in visual perception [12]) akin to the homogeneity detection strategy that allows subjects to determine that a target is not present when there is high distractor similarity [13–15]. Our left parietal patients' shortest response time in target-absent trials in the second block may mirror the same symmetry detection advantage. Indeed, Arguin and colleagues [16] have reported that left parietal patients without neglect show significant benefits from display homogeneity. Right hemisphere neglect patients, however, are well known to have disturbed perception of global stimulus properties [e.g., 17] and therefore might not be able to recognize quickly the geometric "perfection" of the plain distractor pattern. This interpretation is further supported by the "flat" performance of our right hemisphere group without neglect, which unlike normal controls and left parietal patients, never showed an advantage in the absent target condition.

Our results are consistent with the view that there is no direct detection of absence in neglect, or, in Kinsbourne's words [18], that there are no analyzers signaling "nothing there." In a standard setting, the neglect patient, lacking such analyzers, "completes" his percept [19–21] by "filling" the missing part, and so experiences nothing dissonant in his visual world. In our nonstandard experimental setting, however, the target is an isolated stimulus detail and cannot be "filled-in" by a perceptual completion process. Its presence or absence must therefore be detected or inferred. As we argued already, the control subjects seem to be detecting "absence" through a match between the stimulus display and the perceptual template. The neglect subjects, on the other hand, cannot execute this match, and only infer target absence by a failure to see it in a "reasonable" amount of time.

A second interpretation of our findings would take the longer response times as evidence of generally lower perceptual confidence associated with judgements of absence. Although the neglect syndrome is characterized by steadfast denial of deficit and, more specifically, by a confident denial of contralesional stimuli, it is likely, nonetheless, that the perceptual system develops automatic (and unconscious) compensating strategies. Repeated perceptual errors might create a "wariness" about stimulus absence, which would then carry over into the laboratory. If this explanation is correct, then the response time pattern observed in this study could be used as a measure of precisely this kind of coexistence of subjective unawareness and a perceptual "awareness" of deficit in neglect patients.

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